Building Above-Code Walls

Four design/build teams solve the puzzle of high-performance wall construction—in four different ways

BY TED CUSHMAN

Building an insulated wall to meet code is a no-brainer; the code book will tell you what to do. But if you're trying to surpass code and build, say, a Passive House or a zero-energy home, there's no simple road map.

In the next eight pages, *JLC* brings you four real-world examples of high-performance wall systems, each designed and built by a different team, but all tailored to roughly the same New England climate. We asked each team to draw and describe its wall system's construction details, including the tie-in to the roof and foundation, and to explain how its system handles heat conduction, air infiltration, and moisture control.

Each wall beats code, and each has its pros and cons. All four of the building/design teams are learning as they go, and these examples are at various points in a process of constant improvement in materials and methods.

For reasons of space, we've left out an important topic: detailing the window and door openings. Look for more about that at jlconline.com in the weeks and months ahead.

Photo: Phil Cyr

BELFAST, MAINE, COHOUSING UNITS

Designed and built by Matthew O'Malia and Alan Gibson, GO Logic

Our wall system forms part of a set of two-family and three-family designs that we developed for a 36-unit multifamily cohousing project in Belfast, Maine. The design is guided by the Passive House building standard, and the finished buildings meet the criteria for Passive House certification. (However, it's up to the individual homeowners to apply for formal Passive House status, and so far none of the homes are officially certified.)

The wall system consists of an inner stick-framed 2x4 stud wall, insulated to R-13 with dense-packed blown cellulose **(A)**. Outboard of this wall, we apply 8 ¼-inch-thick, R-32 SIPs (structural insulated panels) supplied by R-Control (r-control.com). The entire wall system, including drywall and wood shingle siding, has an R-value of 46 (13+32+.45+.5).

The wall system is airtight at the exterior skin of the SIPs, where we seal the joints with tape. However, we also establish an airtight vapor-control boundary at the inboard face of the SIPs to prevent interior moisture from penetrating the panel joints and condensing near the cold exterior in winter.

Construction proceeds as follows: After the foundation slab is poured, we frame and brace the first-story stud walls, frame and deck the second floor, and frame and brace the second-story walls. Then we apply the SIPs to the outside of this stick frame. As we stand up and attach the SIPs one by one, we apply beads of R-Control adhesive sealant to the EPS foam and also to the edges of the inner OSB skin of the SIPs. We bed the panel bases in sealant and apply sealant to any penetrations or gaps (see photo at right).

At the top of the wall, we extend the ceiling air barrier (Zip sheathing) under the truss heel and seal it to the outer airtight skin of the SIPs using tape **(B)**. To integrate the wall system air and vapor barrier into the slab foundation, we fold the heavy plastic sub-slab vapor barrier around a PT plywood sill under the SIPs panel and sandwich the end between the mudsill and the bottom plate of the inner wall **(C)**. Then we seal the corner before setting the SIPs.

In the course of building out the 36-unit Belfast project, our methods have evolved. Most of the improvements to our system have come from our carpenters in the field—we send the details out to them, they start using them, and often they find better ways to accomplish the goals. With practice, our results have also improved: Our latest blower door test results came in at 0.21 ACH50.

A: Wall Assembly (Plan View)

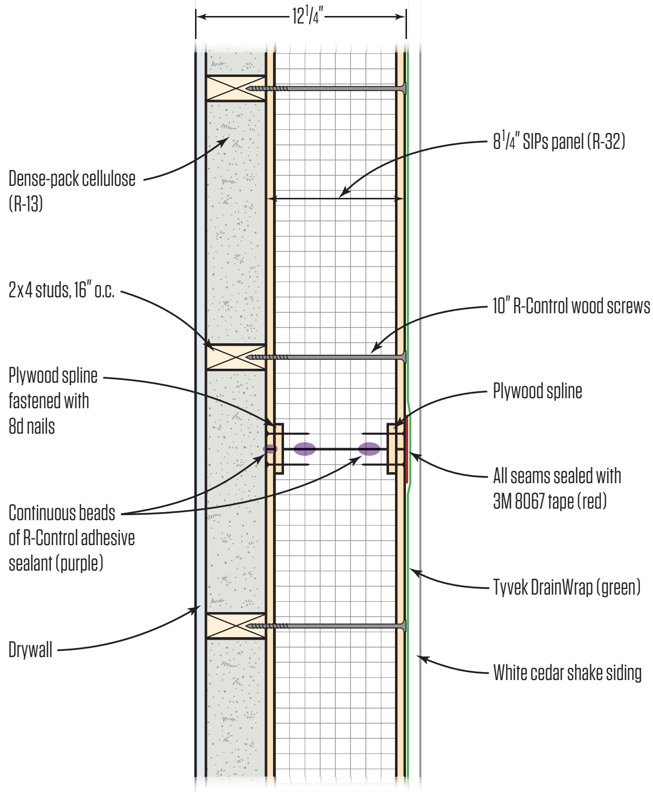
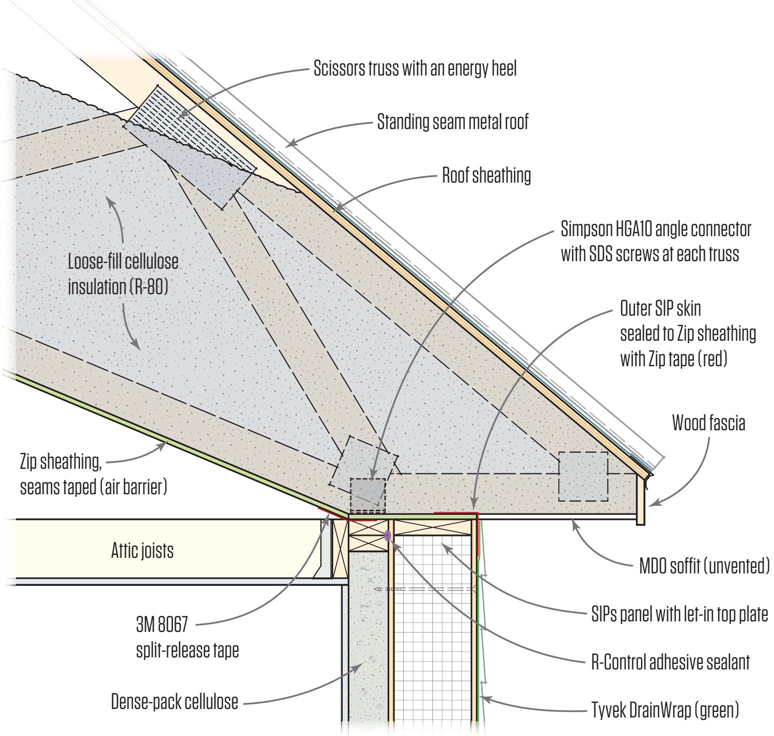
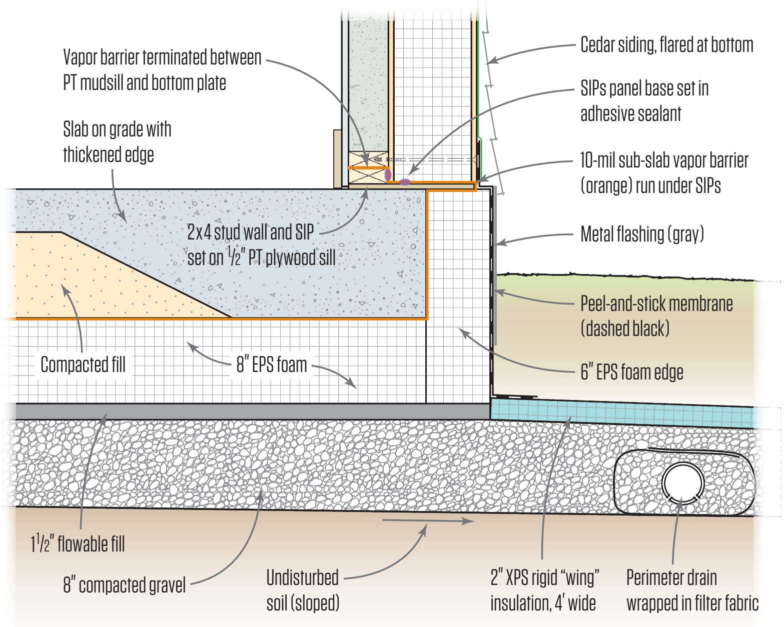


Photo: Ted Cushman

B: Roof-to-Wall Detail



C: Slab Edge Detail



(A) The load-bearing 2x6 stud wall at the core of the GO Logic wall system supports the second floor and roof loads. After the walls are braced, crews fasten SIPs to the exterior one at a time using 10-inch R-Control wood screws. To maintain a continuous airtight vapor-impermeable boundary at the inner face of the SIPs, crews apply beads of R-Control Do-All-Ply adhesive sealant to the edge of each inner panel face before standing the next panel. Adhesive sealant is also applied to the edges of the panel foam cores in each joint, adjacent to the panel spline grooves.

(B) At the roof, Zip sheathing applied to the underside of the truss bottom chords provides the air and vapor barrier. To integrate this sheathing with the wall system air and vapor barrier, crews rip a strip of Zip sheathing to cover the full thickness of both the framed and the SIP walls, and apply a strip of 3M 8067 tape onto the bottom side before fastening it to the top plate of the inner wall. The tape has split-release paper, so half of the tape is left flapping inside the building with the paper still on. After the roof trusses are set and the Zip sheathing nailed to the ceiling, crews peel the rest of the tape and seal it to the ceiling sheathing to complete the airtight joint.

(C) The foundations are reinforced concrete slabs-on-grade placed in an EPS insulating form system on top of a sub-base of compacted stone dust and self-leveling, non-shrinking "flowable fill." To integrate the sub-slab moisture barrier with the wall system air and vapor barrier, crews lay a heavy plastic membrane across the slab perimeter insulation and double the plastic back over a protective sheet of preservative-treated plywood. Then they fold the plastic up and onto the PT mudsill, where it is covered and secured by the bottom plate of the inner wall.

MAINE SINGLE-FAMILY HOME

Designed and built by Chris Corson, EcoCor Design/Build

The wall system shown here is an improved version of the system I used for the house I built in Knox, Maine, in 2011 (see "An Affordable Passive House," *JLC* May/12 and Jun/12). Since building that prototype house, I've switched to some advanced European materials for air-sealing and moisture management that weren't on the U.S. market back then.

We start with an inner 2x4 stud wall, sheathed on the exterior side with OSB **(A)**; all joints and nail lines are sealed with Pro Clima Tescon Vana tape (fourseven five.com). The OSB layer is airtight, and also braces the structure. Next, we fasten 11⅞-inch wood I-joists to the outside of the walls, driving 4-inch GRK RSS structural screws through the flange and OSB sheathing into the studs. As a weather barrier over the I-joists, we apply a vapor-open waterproof fabric from Pro Clima called Solotex Mento Plus.

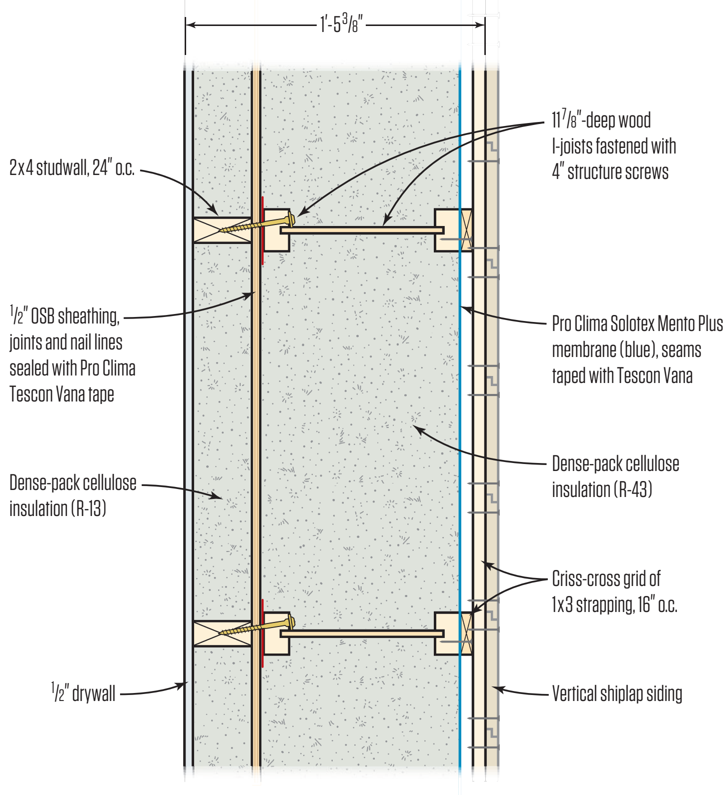
We double strap over the fabric to create an air space behind the siding. For vertical siding (barn boards or shiplap), we apply vertical strapping along the length of the I-joists, then horizontal strapping for nailing. But if the plan is for horizontal siding, we first nail horizontal strapping across the I-joist ribs, then apply vertical strapping for nailing. Finally, we fill both the inner 2x4 wall and the outer I-joist assembly with blown-in dense-pack cellulose insulation for a total wall R-value of 56.

Our roof system has also evolved. We're still using raised-heel trusses, aligning them over the wall studs and insulating the attic with several feet of loose-fill cellulose. But instead of skinning the underside of the trusses with OSB and tape to form the airtight second-story ceiling, we now staple Pro Clima Intello Plus, a fabric reinforced to support insulation, under the trusses and tape the seams, then strap the ceiling for drywall **(B)**. To tie that under-ceiling fabric into the taped OSB sheathing that forms our wall's airtight control layer, we apply a strip of Pro Clima DA-S polypropylene fabric over the top of the wall plate before setting the trusses, and tape it to the OSB layer and to the ceiling fabric with Pro Clima Duplex double-sided tape.

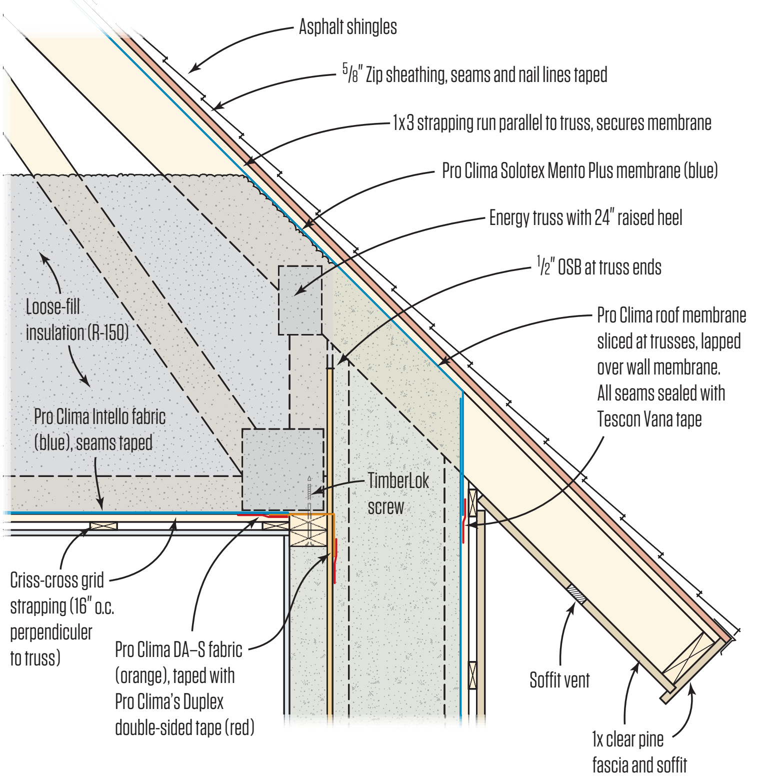
Outboard of the concrete foundation wall, there are 6 inches of Type IX EPS insulation, which matches up with the insulated cavity of the outer I-joist assembly **(C)**. The top of the concrete sill is sealed with Prosoco R-Guard FastFlash. To connect our airtight wall to the foundation sill, we tape the OSB sheathing layer to the sealed concrete with Pro Clima Budax butyl adhesive tape.

Photo: Ted Cushman

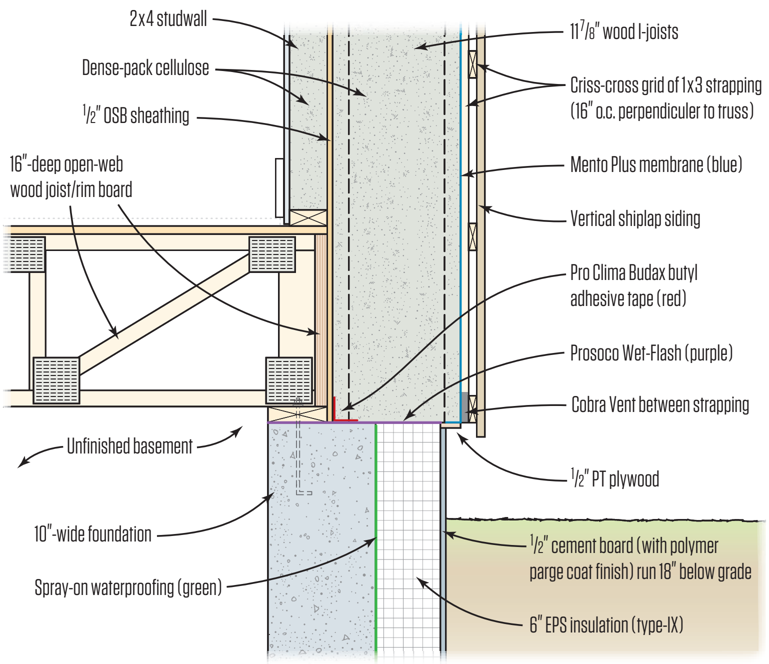
A: Wall Assembly (Plan View)



B: Roof-to-Wall Detail



C: Wall-to-Foundation Detail



(A) EcoCor's wall system is based on a simple stick frame with OSB sheathing, which then gets wrapped in an outer blanket of wood I-joists. The inner frame's sheathing is taped at joints and nail lines. After the house is framed, sheathed, and roofed, the I-joists are screwed into the wall studs. (We typically use 12-inch I-joists, but on some projects have upsized to 16-inch I-joists.) Both the I-joist cavities and the inner stud walls are filled with dense-blown cellulose insulation, for a total wall R-value of about 56 (not including membranes). The system is airtight at the plane of the OSB and is vapor-open to the inside or the outside.

(B) Where the wall system meets the roof assembly, the airtight boundary runs across the wall plate to the underside of the truss ceiling. To accomplish this, the crew lays a strip of airtight fabric across the wall plate before setting trusses, taping the fabric to the OSB on the outside of the stud wall and to a layer of vapor-control Intello Plus fabric stapled to the underside face of the trusses on the ceiling inside. Self-sealing tape is applied over the staple lines, and strapping along the trusses secures the fabric. The ceiling is cross-strapped for drywall, and drywall screws are sized so they will not poke through the strapping or punch holes in the fabric. The roof is insulated to about R-150.

(C) The house shown here sits on a full basement foundation. The basement walls are poured using conventional formwork and then insulated with 6 inches of expanded polystyrene (EPS) rigid foam. The insulated I-joist wall cavities meet up with the foundation insulation. To complete the airtight boundary from the wall to the foundation, the OSB sheathing extends down past the floor system rim board to the concrete sill, and tape is applied to the joint between the sheathing and the waterproofed sill.

"AVALON," A CONNECTICUT FARMHOUSE

Designed by Russell Campaigne, Campaigne Kestner Architects; built by Phil Cyr, J & P Building and Remodeling

Our wall example is part of a zero-energy single-family house built for the tenant farmer of an organic farm in rural Connecticut. The owners wanted a sustainable, healthy, and self-sufficient home. Using REM/Design to analyze the cost-benefit trade-offs, we designed the envelope to keep the home's energy demand low enough that heating and cooling can be supplied by a 1-ton Mitsubishi Mr. Slim mini-split heat pump. That left room in the budget for rooftop solar electricity panels with enough capacity to operate the house at net-zero annually.

The wall is framed with 2x4 studs 16 inches on-center and is sheathed with Zip System OSB panels taped at the joints for airtightness **(A)**. The stud bays are filled with open-cell spray foam insulation. (The original spec was for blown cellulose, but the local insulation contractor charged less to install foam.) Over the sheathing, we applied two layers of 1.5-inch foil-faced rigid polyiso insulation, for a total-wall R-value of 44. We fastened the first layer with 2-inch roofing nails and fastened the second layer through vertical strapping using 6-inch screws with 1½-inch fender washers.

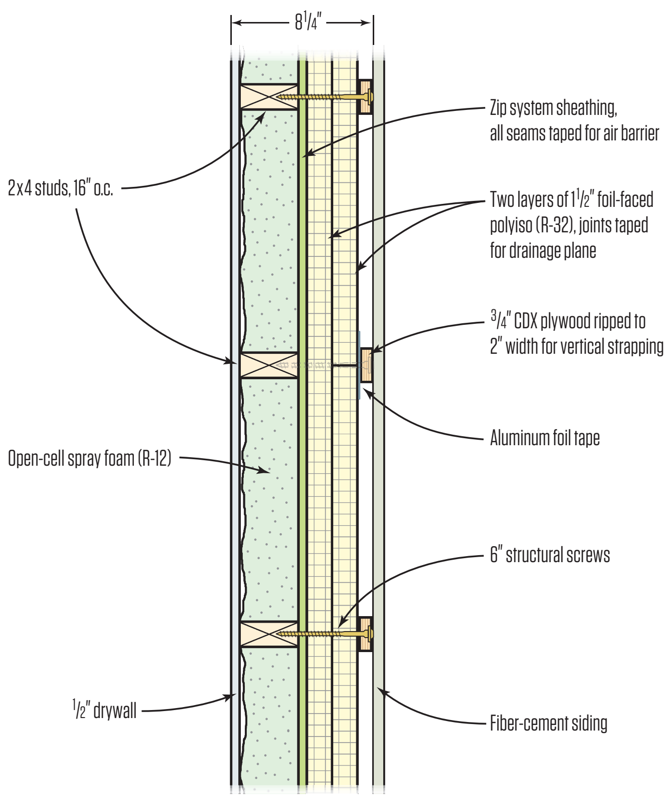
The exterior foam reduces thermal bridging at the wall studs, and the foil facing supplies a drainage plane for the fiber-cement lap siding applied over vertical strapping ripped from ¾-inch CDX. The foam seams are taped with Thermax aluminum foil tape.

Because the farmhouse basement is to be used for cold storage and washing of farm produce, we thermally isolated it from the conditioned living space upstairs by insulating the first-floor joist bays with spray foam insulation. We made the basement ceiling airtight by screwing Zip sheathing to the underside of the floor joists and taping the seams **(C)**. Connecting that airtight floor to the wall system was tricky. We laid a wide strip of Tyvek housewrap down on the foundation sill before framing the floor. After the framing was complete, we taped the Tyvek to the wall sheathing and to the underfloor sheathing with Tyvek tape.

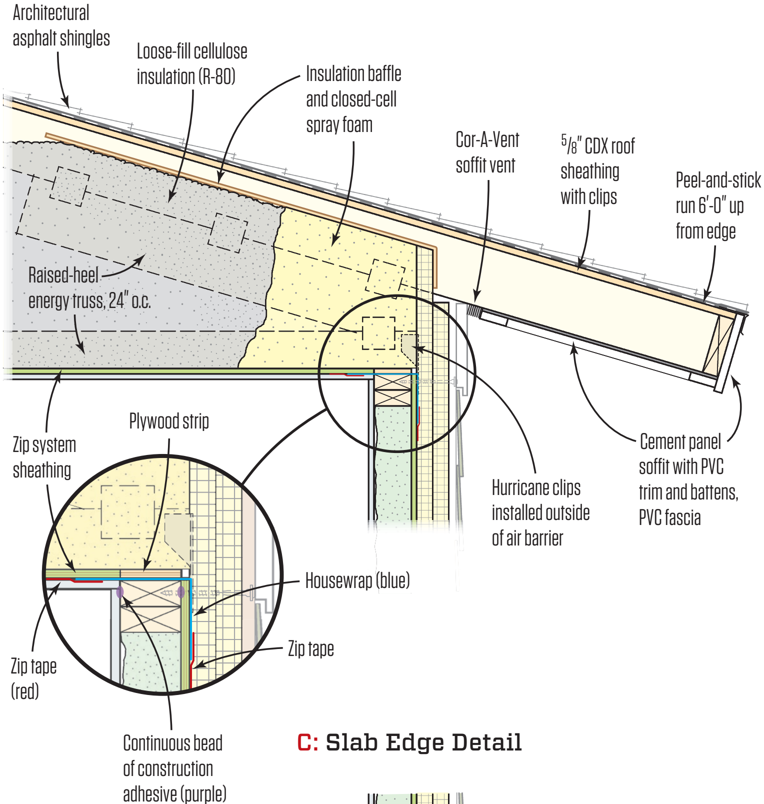
The truss roof is insulated to R-80 with loose-fill cellulose **(B)**. At the top of the stud wall, we applied Zip flashing over the wall plate, adhering it to the inside and the outside edges of the plate, and protected it by nailing a strip of Zip sheathing along the top of the top plate. We also sheathed the underside of the trusses with Zip sheathing, taping the seams, and taping the sheathing to the wall plate flashing to complete the air seal.

Photo: Phil Cyr

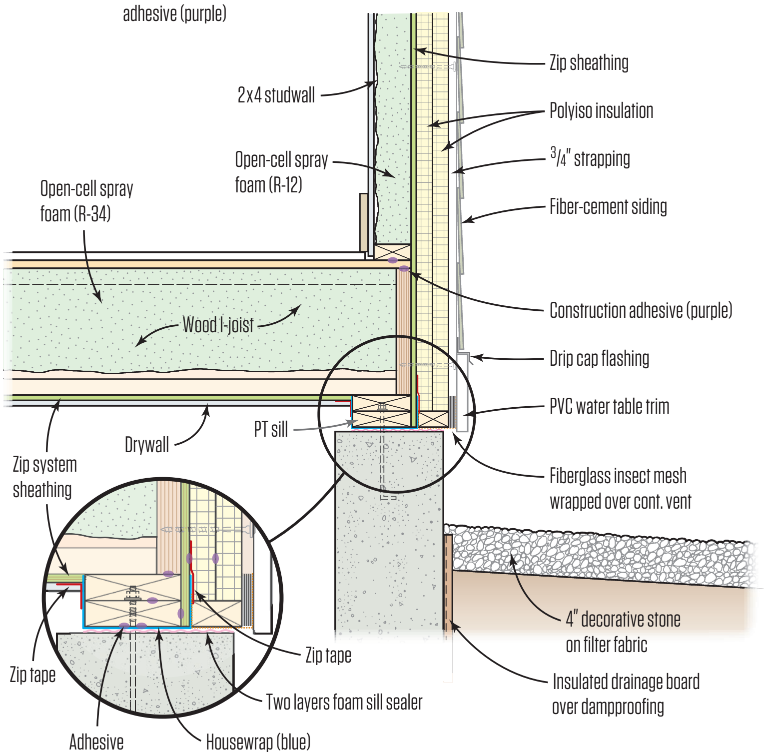
A: Wall Assembly (Plan View)



B: Roof-to-Wall Detail



C: Slab Edge Detail



(A) The structural wall is a 2x4 stud frame with Zip System exterior sheathing. Over the taped Zip panels, the crew attached two layers of Tuff-R foil-faced rigid polyiso foam insulation (R-7 per inch), fastening the first layer with roofing nails and the second layer with long screws. Tuff-R was chosen because it's easily available on the local market and functions as a vapor barrier against interior moisture as well as a drainage plane material for exterior bulk water (wind-driven rain). Strapping over the foam, attached with 6-inch GRK RSS structural screws, creates a drainage space and provides nailing for pre-primed cementitious lap siding.

(B) The truss roof is insulated to R-80 with loose-fill cellulose. The air barrier at the ceiling plane consists of Zip System sheathing nailed to the underside of the trusses. To connect this ceiling air barrier to the air barrier at the wall sheathing, Tyvek was laid down over the wall plate and sealed to the plate's top and sides. Tape along the interior edges of this flashing completes the seal to the ceiling and the exterior sheathing.

(C) "Avalon" has a full concrete basement that is not conditioned because it serves as a workspace and a storage facility for the organic farm. To isolate the working basement from the living space above, the first-floor joist system was insulated with spray foam and sheathed on the underside with Zip System sheathing, taped at the seams. This sheathing is connected to the Zip sheathing on the outboard face of the exterior wall frame with a strip of Tyvek. The crew sets the Tyvek down on top of the basement wall early in the construction process, before placing and anchoring down the pressure-treated sill. After the floor and walls were framed, this Tyvek was taped to the underside of the basement ceiling and to the face of the first-story wall frame using Tyvek tape.

NORWICH, VERMONT SINGLE-FAMILY HOME

Owner-designed, with Christopher Smith Architect; built by Hazen Hill Construction

The wall system in this example grew out of a dialogue between the homeowners and the architect. The owners, a visual artist and her retired art-professor husband, approached us with a nearly complete design after working with several other architects and builders. Our challenge has been to realize their distinctive artistic vision for their home, along with their very ambitious energy-efficiency goals, while also working within the hard limits of their budget.

We chose the simple double-stud-wall method for this house mostly because of budget issues. The interior 2x4 wall, framed at 16 inches on-center, supports the first-floor frame and roof system **(A)**. It is tied to the outer wall frame with 4x12-inch gussets sawn from ½-inch plywood and is x-braced with metal straps. The outer wall is sheathed with plywood, covered by a skin of Grace Ice & Water Shield. The 12-inch open cavity in the wall is filled with blown-in dense-pack cellulose (R-43).

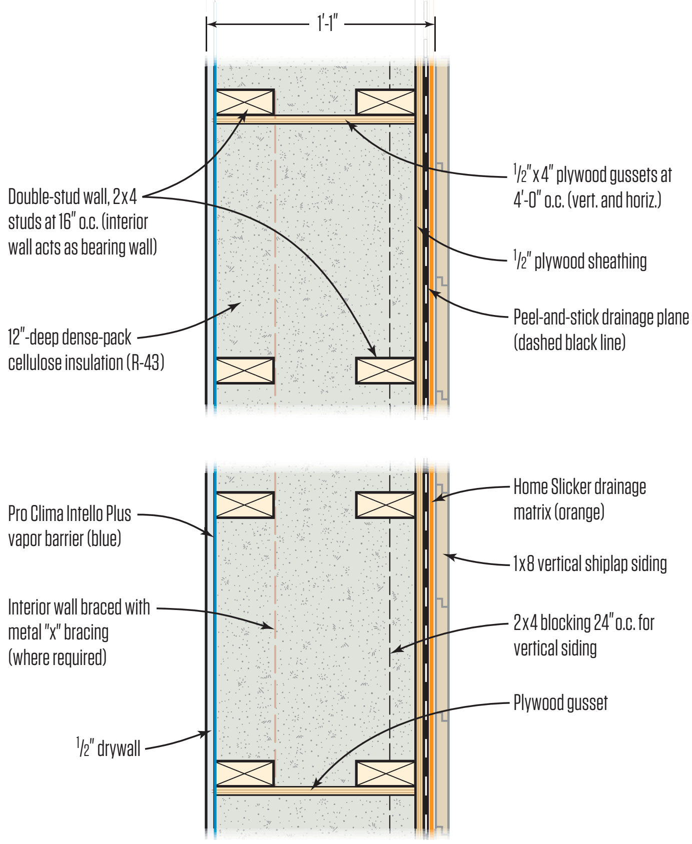
To create a high-ceiling effect in the open-plan first story, the floor above is framed with trusses with steel webs left exposed to below. The low-slope roof is framed with wood I-joists **(B)**. At the top of the second story exterior wall, the Ice & Water Shield laps over the wall edge onto the roof sheathing. (The 2x6 eaves overhang was attached afterward.) The roofing material is a fully adhered PVC membrane, so the air and vapor barrier for the wall, located at the outer plywood skin, continues on to the top surface of the roof.

The foundation for this house is a 6-inch reinforced slab poured in an EPS insulated forming system, as developed by Chris Corson (see "An Affordable Passive House," *JLC* May/12 and Jun/12). We tied our wall system to this foundation by placing a 12-inch-wide plate of half-inch pressure-treated plywood to span the slab and the perimeter insulation **(C)**. The interior wall plate sits on this plywood plate and is anchored to the concrete slab. The outer wall plate, which does not carry floor or roof loads, rests on the plywood plate above the foam. The 15-mil Stego Wrap vapor barrier under the slab foundation runs under the plywood plate, folds up, and is sealed to the plywood skin of the outer wall frame with peel-and-stick membrane.

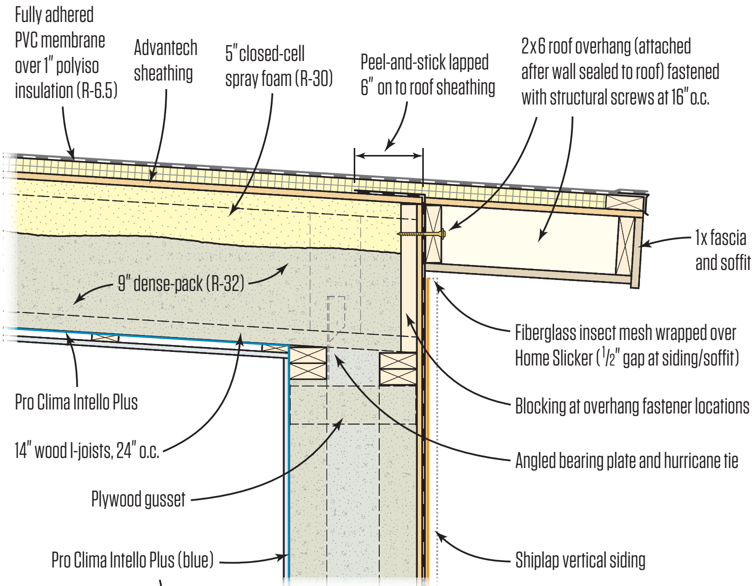
Ted Cushman is a freelance writer based in Peaks Island, Maine. He is editor of the Coastal Contractor newsletter and has been a regular contributor to JLC *since 1993.*

Photo: Ted Cushman

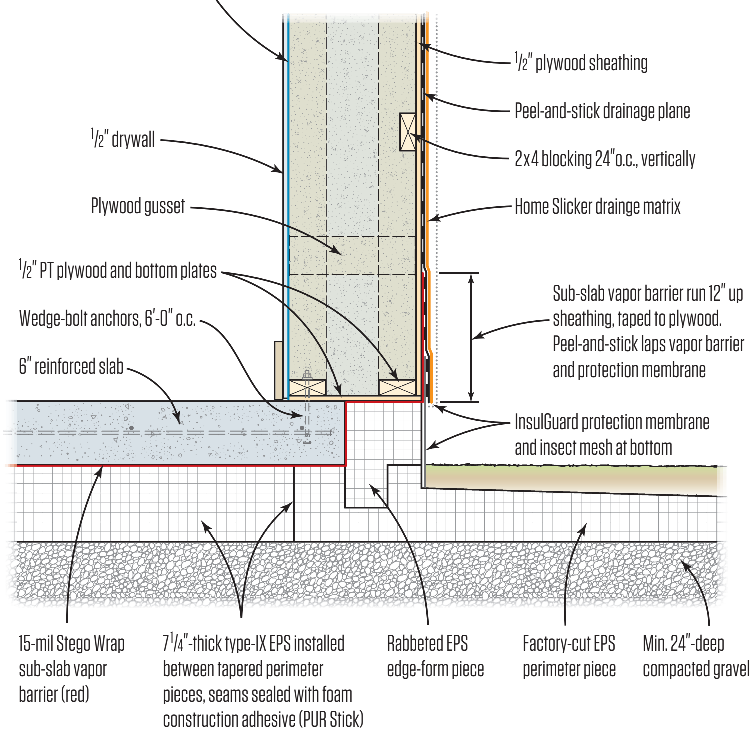
A: Wall Assembly (Plan View)



B: Roof-to-Wall Detail



C: Slab Edge Detail



(A) The wall system is a 12-inch-thick, double-2x4 stud wall, sheathed on the outside with 1/2-inch plywood. The interior wall frame is supported by the super-insulated concrete slab foundation; the outer wall is non-load-bearing. The wall is filled with 12 inches of blown-in dense-pack cellulose insulation. The Grace Ice & Water Shield drainage plane, installed over the outer wall sheathing, also serves as a combined water and vapor barrier for the house, reflecting the designer's assessment that exterior bulk water (wind-driven rain) represents the greatest moisture threat for the building in the Vermont climate. The system is designed to dry to the inside through the Intello Plus membrane. (The house is equipped with an energy-recovery ventilator for heat and humidity control.)

(B) Where the wall meets the roof assembly, the Grace Ice & Water Shield laps over the edge of the roof sheathing. Projecting eaves are framed onto the edge of the roof and sheathed after this wall-to-roof seal is formed. Then, a fully adhered PVC membrane roof is installed over the Advantech sheathing of the low-slope roof, maintaining the home's air and moisture barrier at the exterior face of the building.

(C) The house is built on a reinforced concrete slab foundation, poured in a super-insulated forming system supplied by Branch River Plastics, in Smithfield, R.I. The vapor barrier under the slab, a 15-mil Stego Wrap polyethylene sheet, wraps under the 1/2-inch plywood bottom wall plate, extends up the wall sheathing, and is adhered to the wall sheathing with peel-and-stick membrane, integrating the sub-slab vapor barrier with the wall's exterior drainage plane and vapor barrier.